Tangentially Viewing Soft x-ray Camera on Textor

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Abstract.

A tangentially viewing soft x–ray camera has been installed and operated on TEXTOR tokamak. It gives pictures of the plasma with high space resolution. The camera is being used to study MHD mode and sawtooth activity. Results of projected pictures are being presented.

Introduction.

Soft x–ray imaging on fusion devices is usually done with cameras that use arrays of pin diode detectors [1] collecting the emission of x–rays emitted along a line of sight.

In most cases a poloidal cross–section is being scanned, whereby several hundreds of such pin diodes may be in use. Nevertheless, the resolution is poor, when 2–dim structures are to be resolved. Sometimes this lack of data can be made up for by assuming, that a plasma of given shape does rotate with constant frequency, however, in cases where this does not apply, a better resolution is required in order to be able to see details; a typical case of this kind is the sawtooth crash. We employ a pinhole camera viewing the plasma tangentially. The tangential viewing direction does give the advantage, that the lines of sight have a shallow angle with respect to the magnetic field–lines; then, making the assumption that the emission were constant along the field–lines, 3–dim structures can be inferred from the 2–dim data (see also [2]).

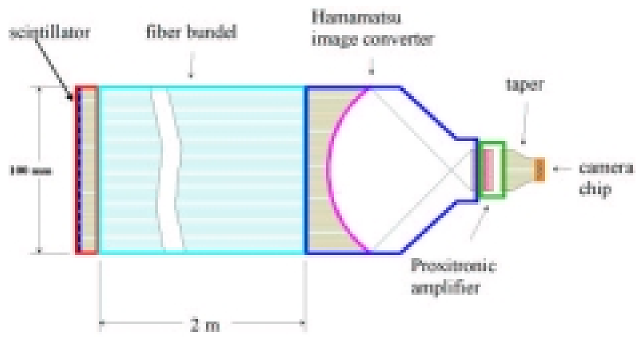

Figure 1: Experimental setup

Experimental Setup.

The device (see fig.1) consists of a pinhole (2 mm dia) camera, a phase plate with a thin scintillator layer with fast response (P47) where x–rays are converted into visible light, Be windows of different thickness for x–ray energy discrimination, a fiber bundle with 15000 plastic fibres, to guide the light away from the region with strong magnetic field, a Hamamatsu imaging tube with electron optics, to reduce the picture size from 10 cm diametre to 2.5 cm dia., a Proxitronic MCP light amplifier and a Dalsa CCD camera of type CA-D1-0256S-333M with frame transfer sensor. The camera space resolution is 256×256 pixels and the framing rate is 200 Hz together with a resolution of 12 bit. Depending on the plasma parameters, the exposure times could be as short as 7μs, being determined by the MCP. The setup of the camera and it's view into TEXTOR is given in somewhat more detail in [3].

The data acquisition is based on VXI modules and consists of an A/D converter (type Hewlett Packard E1429B), the data storage allows for about 200 frames per discharge. The data have been stored in a VXI crate.

To monitor the sawtooth crash, we have developed a sawtooth detector–predictor, which detects the sawtooth crashes, by taking a sliding average of some signal, which does show pronounced sawtoothing. If $\|f(t) - \bar{f}\|$ exceeds a prescribed limit, the event is taken as sawtooth crash. The device measures the period between subsequent sawteeth and gives a trigger burst, if a ready trigger has been set "and" a prescribed time has elapsed after a sawtooth crash.

Together with this detector we have used a Hamamatsu television camera and took pairs of pictures in μs sequence, which then may happen with about 20% chance to be taken just before and after the crash.

Results.

The data obtained did show some noise, which had been picked up along the data transfer line. To remove this noise and to analyze the data in more detail, we fourier transformed them in space and time. On the transformed data we were able to identify the noise picked up on the line (mainly 300 and 600 Hz) and we subtracted it.

Afterwards we transformed back in space – not in time. On the function $f(\vec{x}, \omega = \omega_s)$, where ω_s is the base frequency of the sawtoothing, the whole cross-section involved in the sawtoothing becomes visible (fig.2 centre), the grain structure outside is background noise. Details within the sawtooth crash could not be resolved with the 200 Hz framing rate. The two pictures before and after the crash, which have been taken with the Hamamatsu camera did show pronounced differences, however, just two frames are not sufficient to draw conclusions on the crash mechanism.

Although the time resolution of 200 Hz is usually not sufficient to resolve MHD oscillations, we did have a few cases, where an $m = 2, \quad n = 1$ mode rotated with about 40 Hz and almost constant frequency, being an integer fraction of the camera framing rate. The information on the mode was then found to be almost exclusively in only one of the Fourier components. A resulting picture, namely $f(\vec{x}, \omega_{m=2})$ is shown in fig.3. It shows a quadrupole structure as it is to be expected for a $m = 2$ mode. This quadrupole structure is slightly obscured, because not the whole cross–section is depicted.

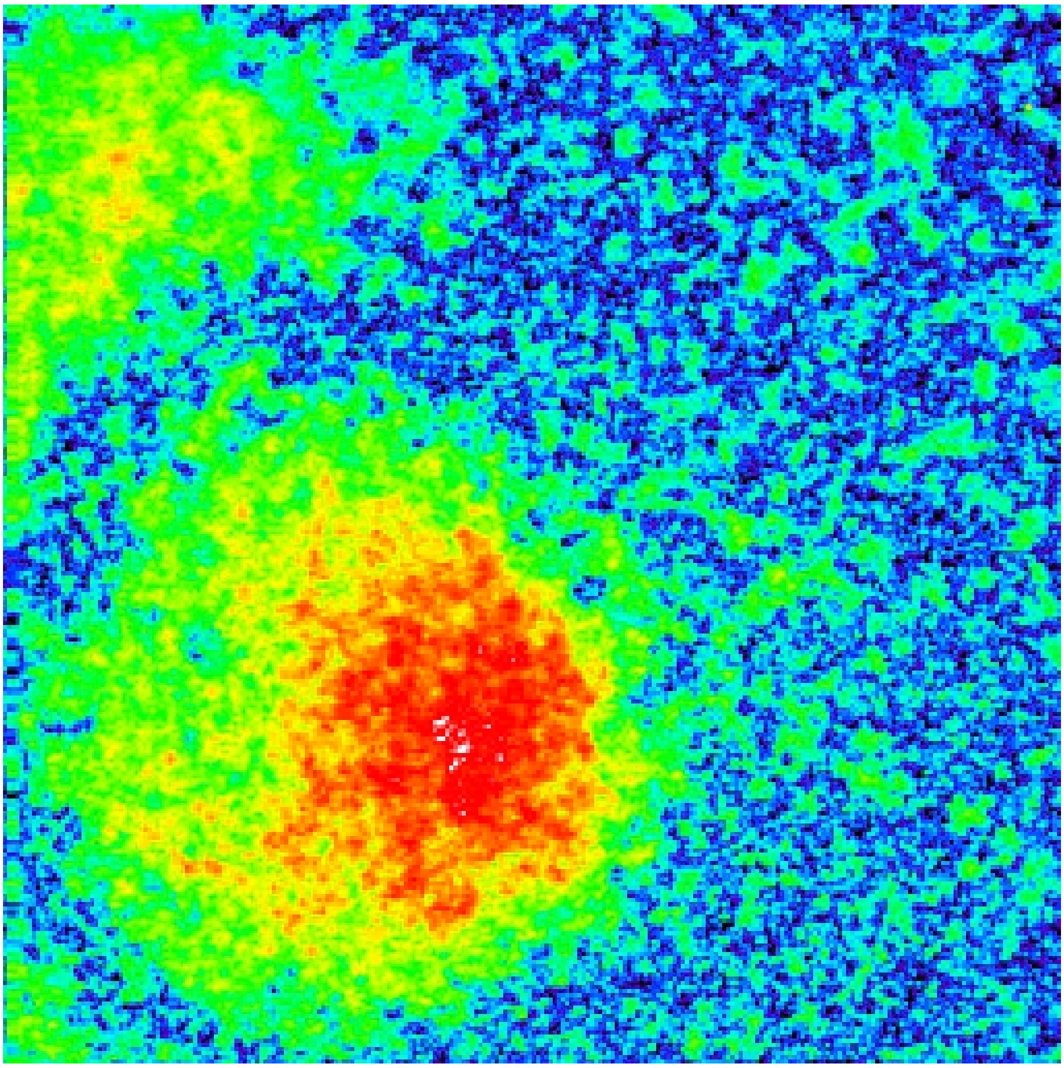

Figure 2: The figure shows the Fourier component, which oscillates with the sawtooth frequency, i.e. a picture of the sawtooth oscillation.

So far we cannot present an inversion of the projected data. Because of the lack of data – we have a 2–dim picture and look at a 3–dim structure – we need some assumption in order to be able to invert. This assumption could be, that the emission is constant along the magnetic field–lines. This inversion in flux coordinates needs still to be done. We can, however, compare our results to a mockup. For the local variation of luminosity in time being due to a MHD mode we make the ansatz

$$f = f_0 \ \cos(m(\theta_H + \iota\varphi) + \phi) \ exp(-((\rho - \rho_{mn})/\delta_{mn})^2) \tag{1}$$

where

$$\theta_H = \theta + d\theta \cdot |(\sin(\theta))| \tag{2}$$

takes care of the fact that the magnetic field lines do have a 'S' shape on the $\{\phi, \theta\}$ surface. Then we calculate the projection, the result is shown in fig.3 right.

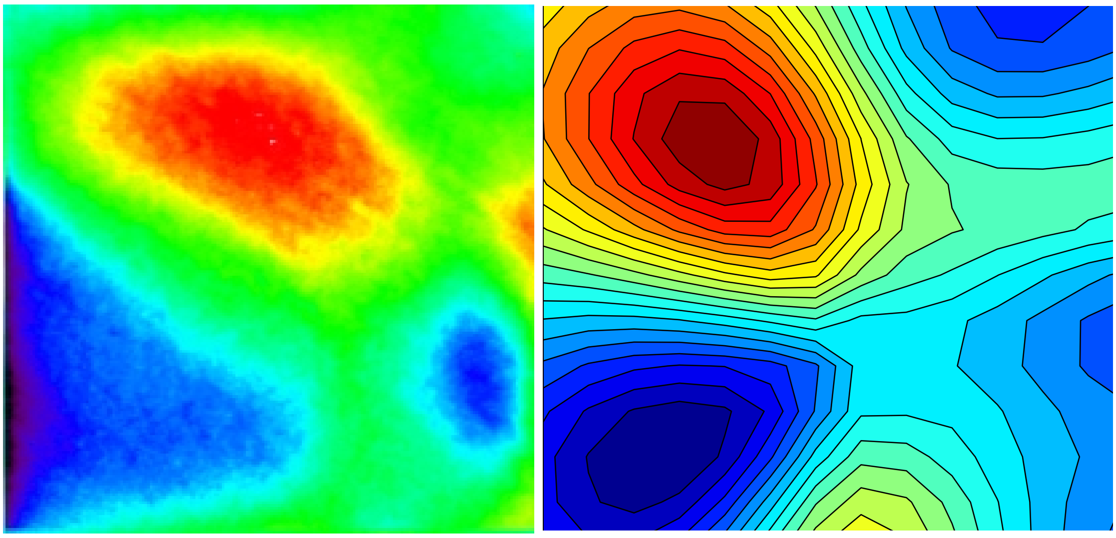

Figure 3: The fourier component,which oscillates with the frequency of the m=2 mode –left– and a simulation of such a case –right

Conclusions.

We have shown, that the soft x–ray camera described can give high space resolution pictures of the plasma, whereby the exposure times can be short enough to resolve MHD phenomena.

The next step will be, to increase the time resolution to be able to study the above phenomena in more detail. The event trigger can then help to identify the phenomena to be investigated and to save storage. As a next step we plan to use during the next experimental campaigns on LHD and on TEXTOR a Kodak camera capable of 4 kHz for full 256 $\times$ 256 pixel mode and up to 40 kHz for reduced resolution.

[1] P.S. Shavrukhin and I.V.Klimanov, Rev. Sci. Instr. 72 (2001)

[2] A. Huber et al., this issue, contr. ID 200141

[3] S.von Goeler et al., Rev. Sci. Instr. 70 602 (1999)

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